An Alloy Steel Composition

The present invention relates to an alloy steel composition and in particular to an alloy steel composition that is suitable for use in the production of metal castings for applications which are subject to highly abrasive wear forces.

Background of the Invention

Metal castings which are used in applications, such as for example autogenous and semi autogenous grinding mills and ball mills, are subject to a large amount of abrasive wear force, which over time, gradually wears away at the metal casting until replacement is required.

As such, it is desirable that the metal castings used in these types of applications can withstand a high degree of abrasive wear and also maintain hardness throughout the entire composition of the metal casting.

Previous attempts at producing metal castings with increased abrasive wear resistance have focused on varying the alloying components of steel alloys in order to produce the desired characteristics. In addition, various production techniques, such as air blasting and liquid quenching the metal castings have been used to increase the hardness and thereby abrasive wear resistance of the castings.

Surprisingly, it has been found that if an alloy steel composition is produced which includes the alloying components of copper and nickel, then the resulting alloy steel composition has an increased abrasive wear resistance that provides that the composition is very suitable for producing metal castings used in the applications discussed above.

Summary of the Invention

According to one aspect, the present invention provides an alloy steel composition which

includes the following constituents by weight:

carbon	0.5 – 3.5%
silicon	0.2 – 0.8%
manganese	0.5 – 1.5%
nickel	0.1 – 2.0%
chromium	1.0 – 3.0%
molybdenum	0.1 – 0.5%
copper	0.1 – 2.0%.

Preferably, the percentage composition of nickel is 0.10 – 0.45% by weight and the percentage composition of copper is 0.10 – 0.45% by weight.

Preferably the alloy steel includes the following composition be weight:

carbon	0.75 – 0.90%
silicon	0.35 – 0.50%
manganese	0.80 – 1.00%
nickel	0.25 – 0.45%
chromium	1.90 – 2.30%
molybdenum	0.25 – 0.45%
copper	0.25 – 0.45%.

More preferably the alloy steel includes the following composition be weight:

carbon	0.80 – 0.85%
silicon	0.42 – 0.48%
manganese	0.85 – 0.95 %
nickel	0.32 – 0.38%
chromium	2.05 – 2.25%
molybdenum	0.30 – 0.37%
copper	0.32 – 0.38%.

According to another aspect, the present invention provides a metal casting produced from

an alloy steel composition which includes the following constituents by weight:

carbon	0.5 – 3.5%
silicon	0.2 – 0.8%
manganese	0.5 – 1.5%
nickel	0.1 – 2.0%
chromium	1.0 – 3.0%
molybdenum	0.1 – 0.5%
copper	0.1 – 2.0%.

Preferably the metal casting has a substantially pearlitic microstructure throughout its entirety. Furthermore, the hardness of the casting is greater than 310 HB when measured using the Brinell Hardness Test. Preferably, the hardness of the casting is greater than 335 HB and more preferably still greater than 350 HB

According to another aspect, the metal casting may be used in applications which are subject to high abrasive wear forces. Preferably, the metal casting may be used as a component in autogenous grinding mills, semi-autogenous grinding mills or ball mills, and more preferably still, the components are lifter bars, liners, pulp lifters and/or grates.

Preferably after about 50 to 100 mm of wear has occurred on the metal casting, the hardness of the casting is greater than 310 HB and preferably greater than 330 HB.

According to a further aspect the present invention provides a method of producing a metal casting composed of an alloy steel composition, which includes the following constituents by weight:

carbon	0.5 – 3.5%
silicon	0.2 – 0.8%
manganese	0.5 – 1.5%
nickel	0.1 – 2.0%
chromium	1.0 – 3.0%
molybdenum	0.1 – 0.5%

copper 0.1 – 2.0%,

characterised wherein the method includes the steps of:

i. pouring the molten alloy composition into a metal casting mould;
ii. cooling the metal casting at ambient temperature; and
iii. grind casting and gauge to profile.

Brief Description of the Figures

The present invention will become better understood from the following detailed description of a preferred but non-limiting embodiment thereof, described in connection with the accompanying drawings, where in:

Figure 1 is a photograph of a metal casting produced from an alloy in accordance with one aspect of the present invention; and

Figure 2 is a photograph of a commercially available metal casting used in autogenous and semi autogenous grinding mills.

Detailed Description of the Invention

The alloy steel composition in accordance with one aspect of the present invention includes the following alloying elements: carbon, silicon, manganese, nickel, chromium, molybdenum, copper, with the balance of the composition being principally composed of iron. Other elements which may be present in trace quantities include sulphur, phosphorus, vanadium, aluminium and niobium.

With the addition of copper and nickel, in combination with the specific ratios of the other principal alloying constituents, it was found that the resulting alloy provided a surprising through hardness which made it particularly useful for applications such as autogenous and semi-autogenous grinding mills, ball mills and indeed any application that subjects metal castings to highly abrasive wear forces. Furthermore, upon structural analysis of metal castings produced from the alloy composition, it was found that they have a substantially

pearlitic microstructure.

Metal castings, in accordance with an aspect of the present invention, are produced by preparing the molten alloy composition with the correct proportions of the alloying constituents. The molten alloy is then poured into a mould conforming to the particular shape casting desired. The metal casting is then cooled to ambient air temperature after which the casting is removed from the mould and ground and gauged to the desired profile.

If a metal casting is desired which has a thickness of greater than 300mm it may be desirable to air blast the castings, after cooling, in order to increase their hardness. Furthermore, if the metal castings include thicker sections adjacent to thinner sections, then a further step of tempering may be introduced after the normalising heat treatment.

The present invention will become better understood from the following example of a preferred but non-limiting embodiment thereof.

Example

A trial was conducted to analyse the effect of abrasive wear force upon various metal castings used in autogenous grinding mills. Three different metal castings made of different alloy steels were tested. Test metal casting A was produced from an alloy according to an aspect of the present invention. The two remaining metal castings B and C are commercially available products. The three test metal castings A, B and C were put into service for a period of four months after which time they were removed and examined.

Composition Analysis

Samples of the three test metal castings A, B and C were abrasively cut and constantly cooled with water to avoid overheating so they can be used for chemical and metallographic analysis. Chemical analysis results are given in the following table which were provided using an ARL 3460 Optical Emission Spectrometer.

Table: 1

ID No	C %	Si %	S %	P %	Mn %	Ni %	Cr %	Mo %	V	Cu	Al	Nb
A	0.85	0.45	0.015	0.015	0.9	0.35	2.15	0.34	0.02	0.35	0.05	0.01
B	0.78	0.05	0.028	0.015	0.92	0.06	2.58	0.31	0.018	0.09	0.07	0.01
C	0.67	0.49	0.018	0.013	0.65	0.07	2.29	0.31	0.017	0.09	0.04	0.01

Hardness

Each of the worn test metal castings was surface ground to a dept of 3 – 4 mm on the wear face and hardness tested using an Equotip instrument. Hardness results with specification and testing position are given in the following table:

Table: 2

Metal Spec.	Thin Section HB	Thick Section HB
A	376	333
B	327	310
C	326	285

Metallography

A small section was cut from the wear face of each of the three test metal castings. All specimens were wet ground on silicon carbide paper, polished with 6 & 1 µm diamond and etched using 2% Nital. Examination was performed using a metallurgical microscope at x50 to x1000 magnifications. This revealed a slightly different microstructure for each specification.

Microstructure of the specimen composed of Alloy A – consisted of a tempered pearlite with a very small amount of spheroidal carbide in some insulated areas.

The microscopic examination of the specimen composed of Alloy B revealed a pearlitic microstructure with a network of boundary carbide and a small amount of spheroidal carbide in some areas.

Microstructure of the Alloy C consists of tempered martensite with 0.5% to 1% carbide around the grain boundaries. Also very light etching revealed some micro-cracks in between the grains of the microstructure.

Visual examination

As it can be seen from the photographs in figures 1 and 2, all pieces are heavily worn with no metal flow on the edges. Some pieces of the castings made from Alloys B and C have been worn to very thin sections of only 40 mm around bolt holes while the most warn part of the casting made from alloy A liner is 80 mm in thickness (See the table below).

It has been noticed that areas around boltholes are most affected, so the thickness has been checked and presented in the following table. The thickness results are a good indication of the wear resistance of different metal compositions.

Table: 3

Metal Spec.	Most effected area mm	Least effected area mm
A	110	140
A	110	160
A	80	130
B	70	120
B	70	130
C	40	100
C	40	140

Conclusion

After heat treatment, these grades are expected to achieve a fully pearlitic microstructure with a hardness range on the wear face of 320 HB to 380 HB but some lower hardness can be expected in the middle of very thick section castings as slower cooling occurs in these thick casting sections during heat treatment.

The metal casting produced from alloy C has the lowest performance against abrasive wear force as a result of its martensitic microstructure.

The casting produced from alloy B shows the presence of a carbide network around the grain boundaries, which increased the hardness but in the same time decreases the toughness of the material.

The metal casting produced form alloy A achieved the best performance as a result of its material properties. Through hardness was achieved with a fine pearlitic microstructure with spheroidal carbides in very small-insulated areas. The presence of spheroidal carbide improves wear resistance without decreasing the toughness of the material.

Although several preferred embodiments have been described in detail, it should also be understood that various changes, substitutions, and alterations can be made herein by one ordinarily skilled in the art without departing from the spirit or scope of the present invention.